P&S Modern SSDs

Cutting-Edge Research in SSDs

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Outline

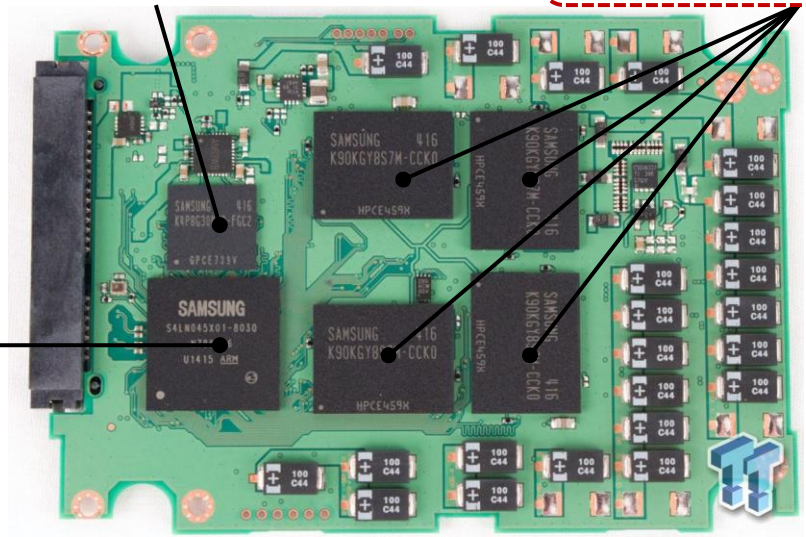
- NAND Flash Basics
- Reducing Solid-State Drive Read Latency by Optimizing Read-Retry, ASPLOS 2021
- Evanesco: Architectural Support for Efficient Data Sanitization in Modern Flash-Based Storage Systems, ASPLOS 2020
- DeepSketch: A New Machine Learning-Based Reference Search Technique for Post-Deduplication Delta Compression, FAST 2022

NAND Flash-Based SSDs

- A complicated embedded system
  - Multiple cores, HW controllers, DRAM, and NAND flash chips

LPDDR DRAM
Metadata store

NAND Flash Chips
Persistent data store



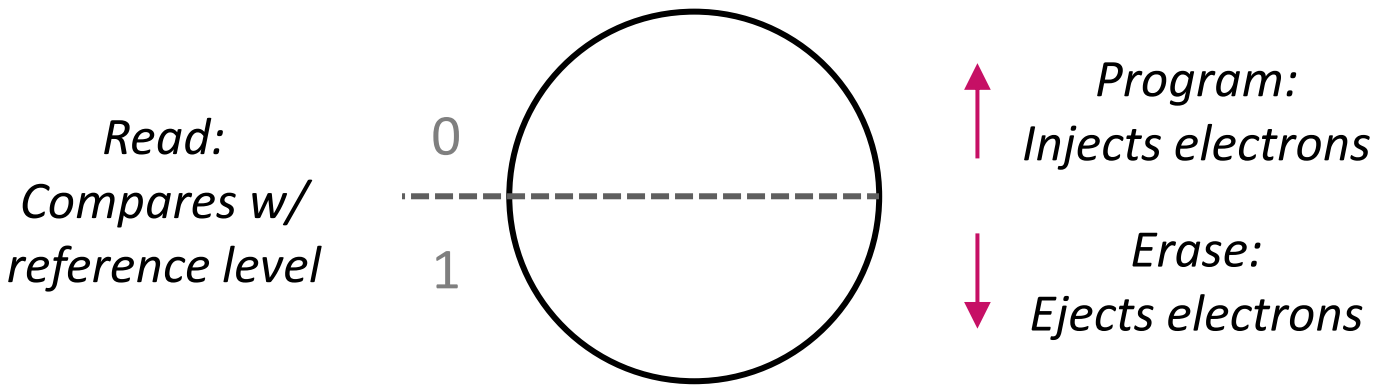
SSD Controller
- ARM Cores
  Running firmware
- HW Flash Controllers
  Chip control, ECC

Unique characteristics
- Erase-before-write
- Limited endurance
- High error rates
- …

Samsung PM853T 960GB Enterprise SSD (from https://www.tweaktown.com/reviews/6695/samsung-pm853t-960gb-enterprise-ssd-review/index.html)

Flash Cell

- Stores data using its threshold voltage (V_{TH}) level
  - Dictated by the amount of electrons (i.e., charge) in the cell
  - The more the electrons, the higher the V_{TH} level



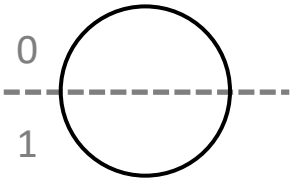
Flash Cell

1. Can change V_{TH} (=charge) in a non-volatile manner

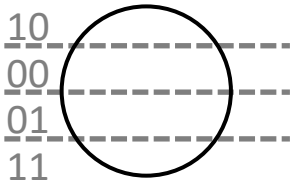
2. Encodes bit data with different V_{TH} ranges

Flash Cell Characteristics

- Multi-leveling: A single flash cell can store multiple bits

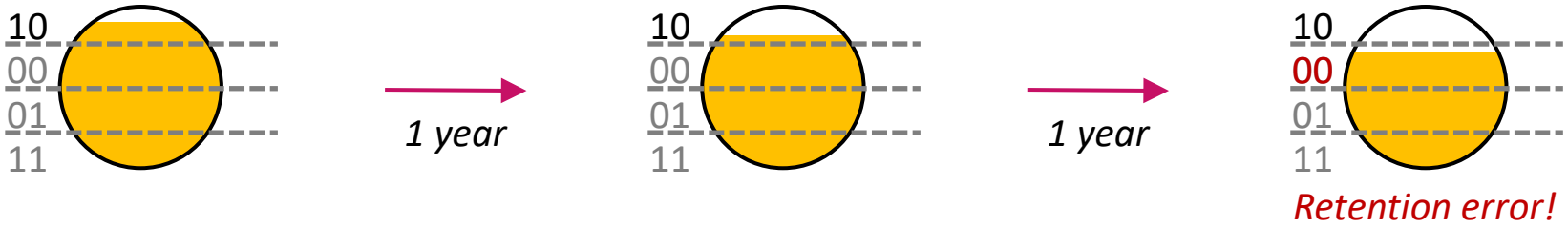


Single-Level Cell (SLC)

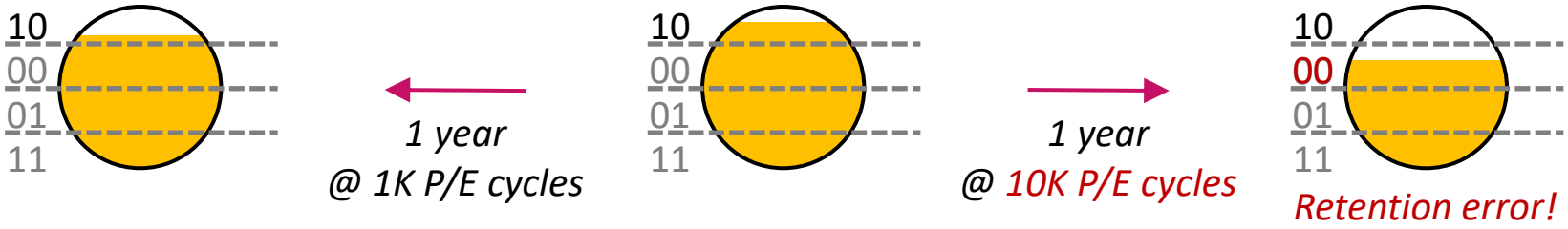


2-Bit Multi-Level Cell (MLC)

- Retention loss: A cell leaks electrons over time



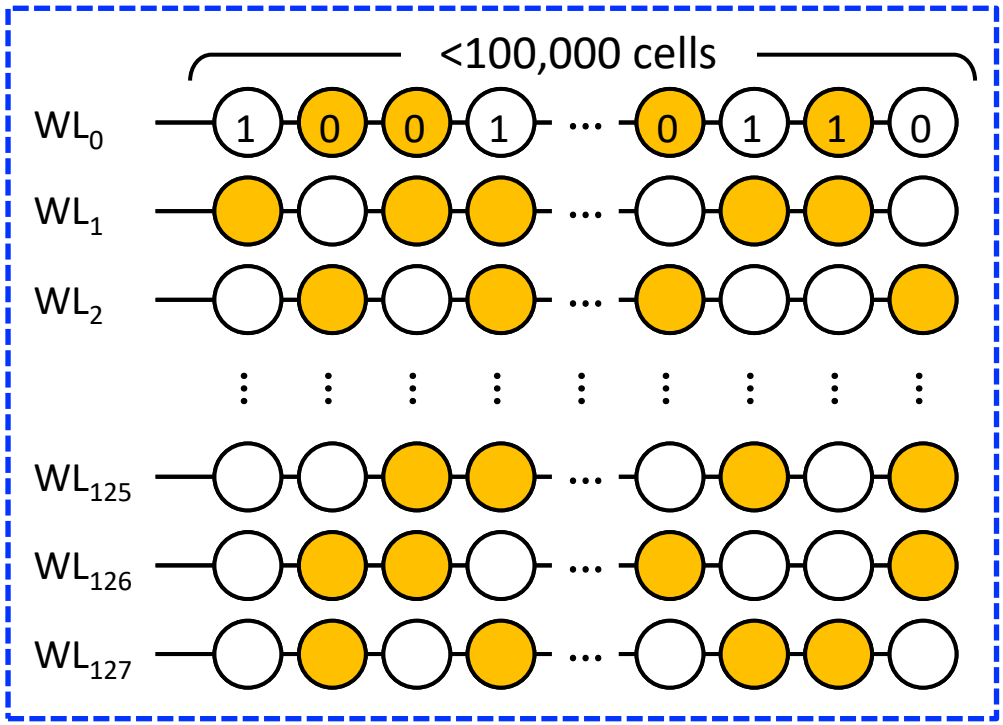
- Limited lifetime: A cell wears out after P/E cycling



Page and Block

- A number of flash cells operate in parallel

Cells in the same wordline (WL)
are concurrently read/programmed



Block (128 WLs)

Cells in the same block
are concurrently erased

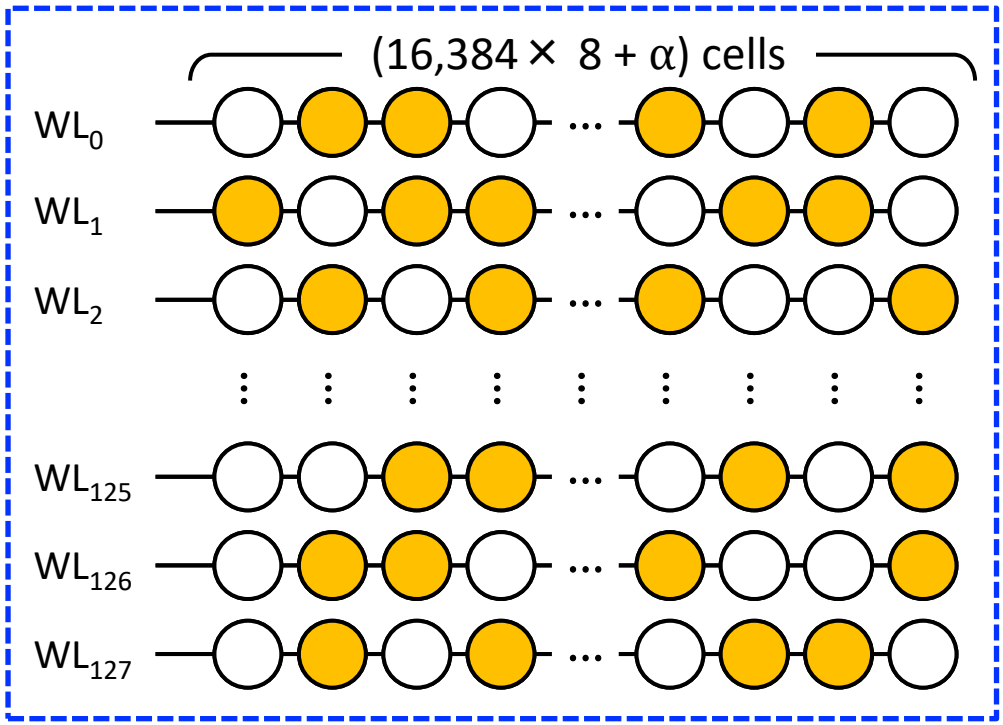
Long latency,
but high bandwidth

No overwrite of WLs
before erasing the block:
Erase-before-write

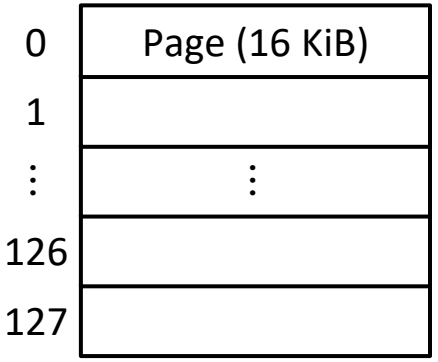
Page and Block

- A number of flash cells operate in parallel

Cells in the same wordline (WL)
are concurrently read/programmed



Block (128 WLs)

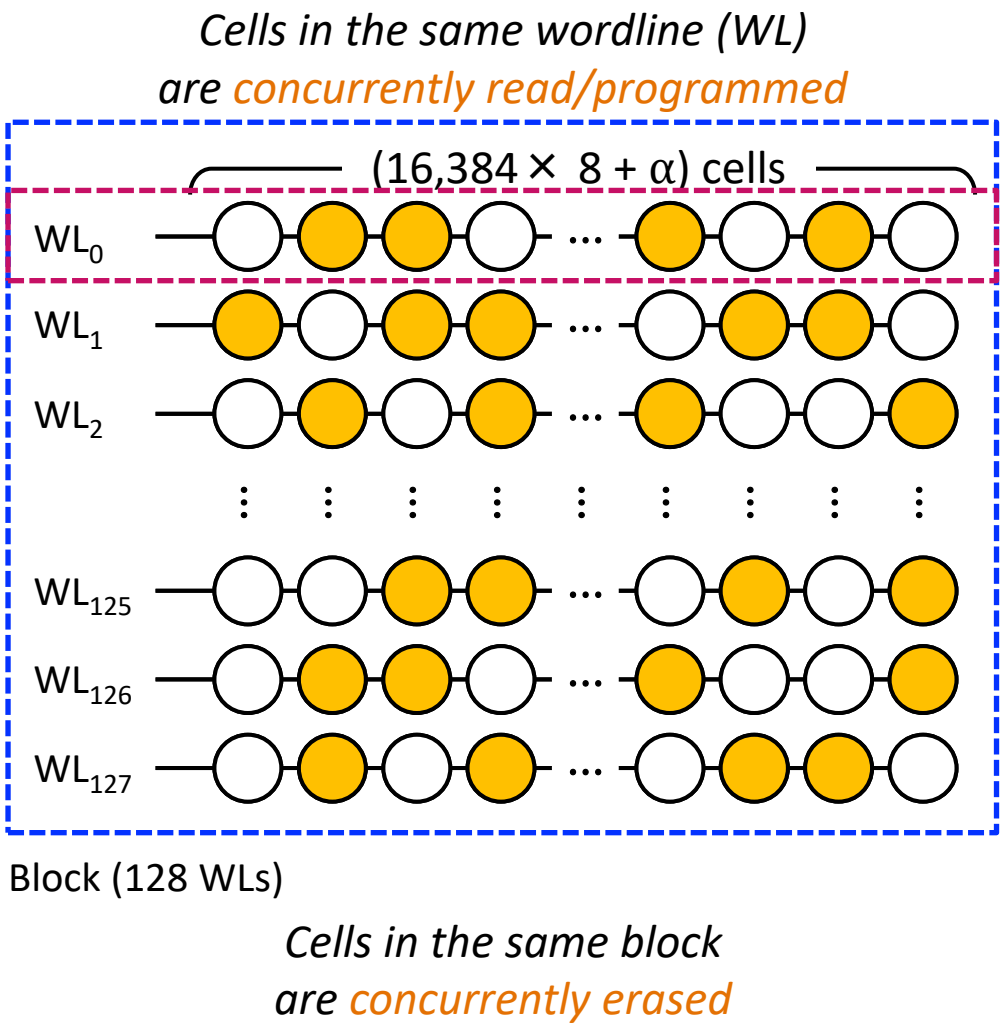


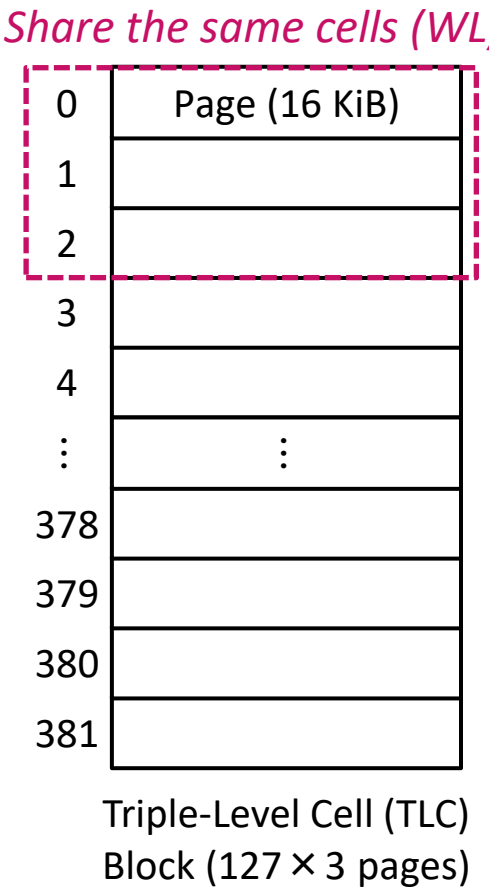
Block (127 pages)

Cells in the same block
are concurrently erased

Page and Block

- A number of flash cells operate in parallel





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